



## Chapter 4. Mathcad Basics

### Key Points:

- PTC Mathcad Prime uses real math notation so we can type in math expressions with our keyboard.
- We can document our calculations using **Text Blocks** and **Text Boxes**.
- There are different kinds of equals signs in Mathcad. For Creo Parametric integration the ones that we will use the most are the **Evaluation** and **Definition** operators.
- We can create variables that stand for different quantities of interest.
- Mathcad has over 400 built-in functions that we can use for our engineering calculations. We can also create our own custom math functions.

### 4.1. Basic Math

Mathcad has more functionality than can be covered in this book. But in this chapter, we'll cover the functionality most relevant to connecting Creo Parametric parts and assemblies to Mathcad worksheets.

As mentioned in the [previous chapter](#), one of the benefits of PTC Mathcad Prime is that it uses real math notation and you don't have to learn any kind of special programming language. To perform math, simply start typing in your values, constants, and variables. (More about the latter two later.) Then simply use addition, subtraction, multiplication, and division using the standard keys on the keyboard.

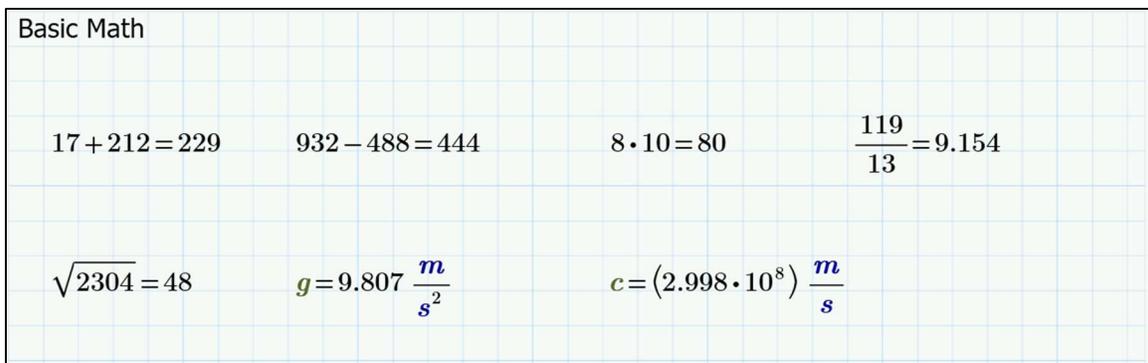


Figure 4-1: Basic math in PTC Mathcad Prime.

These functions are also available in the **Algebra** group from the **Operators** drop-down on the **Math** tab. Using the standard forward slash for division will provide you with a numerator and denominator. You can use inline division from the **Operators** drop-down or the keyboard shortcut of the Control key CTRL and the forward slash.

To apply an exponent, use either the **Exponentiation** operator in the **Algebra** group from the **Operators** drop-down on the Math tab, or the keyboard shortcut of the SHIFT key and 6 – which is also known as the caret or hat key. Again, this is real, intuitive math notation.

To control the order of operations when performing math, you can use parentheses. Typing an open parenthesis (the SHIFT key and 9) will generate both the open and closed parentheses on your worksheet for typing your mathematical expression.

## 4.2. Text Regions

Another advantage of PTC Mathcad Prime is the ability to document your process as you perform calculations. This is critical to ensure that you and others can understand your thinking, logic, and processes later.

In Mathcad you can use Text Regions for documenting your calculations, or whatever information you want to capture about your product.

- A **Text Block**  spans across the width of the page.
- A **Text Box**  has drag handles and can be resized and moved.

Both commands are available from the Regions group on the **Math** tab. Here are examples of Text Blocks and Text Boxes on a worksheet:



## 1 MACHINE DESIGN AND ANALYSIS

### Analysis of a Transmission and Sizing of Hollow Shafts in Bending and Torsion

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A hollow shaft is supported by 2 bearings and transmits input power to a driving gear. The power is transmitted through the driving gear to a driven gear on a second hollow shaft. This second shaft is also supported by 2 bearings and power is subsequently output through a third gear.

Determine

- what are the output torque and shaft speed;
- what are the loads on the bearing sets for the input shaft; and
- what is the nominal wall thickness of the input shaft

Figure 4-2: Text Boxes and Text Blocks.

Both Text Blocks and Text Boxes can be dragged and moved at any time.

*Recommendation: use a Text Box to explain new variables and functions that you introduce.*

You can also use the **Image** command  from the Regions group on the Math tab to insert picture files in your worksheet to add another level of clarity to your engineering calculations.

### 4.3. Equals Signs in PTC Mathcad

There are a variety of different kinds of equals signs in PTC Mathcad Prime that have different uses. The two that come into play most often with integrating Creo Parametric models to Mathcad Worksheets are:

- The **Evaluation** operator, to calculate and show the value of a variable, a function, vector, matrix, or program. This is a simple equals sign (=).
- The **Definition** operator, which defines a variable, function, vector, matrix, or program. This is a colon followed by an equals sign (:=). The keyboard shortcut is the colon : key.

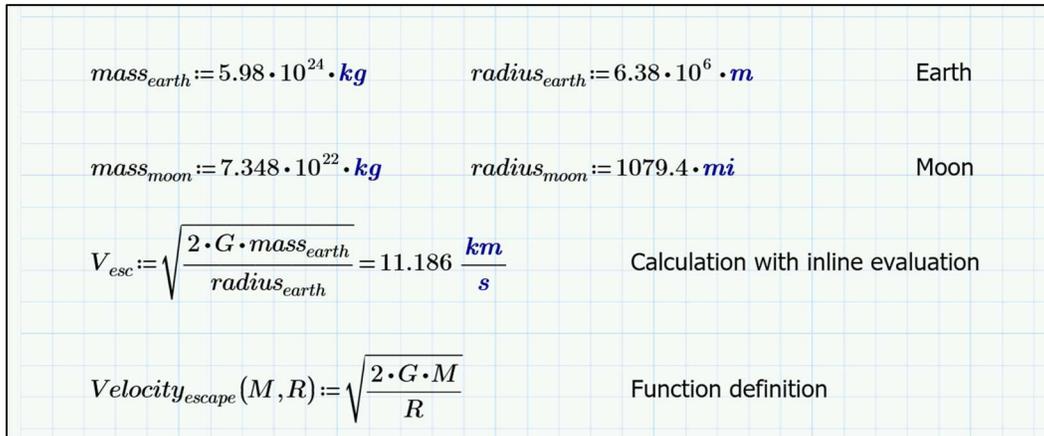


Figure 4-3: Examples of the Definition Operator for variables and functions.

There are other kinds of equals signs, which are of less use when integrating Mathcad with Creo Parametric. These include:

- The **Global Definition** operator discussed in the next section.
- The **Local Assignment** operator, which is used inside of programs. These are discussed in Chapter 5.
- The **Comparison Equal To** operator for evaluating whether a condition is true. This operator is also used in Solve Blocks. This is discussed in section 4.3.2.
- The **Symbolic Evaluation** operator, which is discussed in section 4.3.3.

#### 4.3.1. Global Definition Operator

Mathcad worksheets are evaluated the same way that people read in the Western world: from right to left and then top-to-bottom. Sometimes, though, you may be several sheets deep and want to define a variable or set of units that can be used anywhere in the worksheet.

To do this, you can use the **Global Definition** operator, which appears as three horizontal bars. The command is available from **Math > Operators** and is located in the Definition and Evaluation group. The keyboard shortcut is the CTRL and SHIFT keys with the tilde character ~.

Any mathematical expressions that use the Global Operator are evaluations at the beginning of the calculation cycle. Uses for the Global Definition operator include:

- The ORIGIN special variable for defining the index of the first column and row of a vector or matrix.
- A custom unit.

- A constant that you want used throughout your document.

$radius_{earth} = (6.744 \cdot 10^{-10}) \text{ ly}$	Evaluate earth radius in light years before it has been defined in worksheet
ORIGIN $\equiv$ 1	Vector and matrix origin
$ly \equiv c \cdot yr = (9.461 \cdot 10^{15}) \text{ m}$	Define new unit light year
$G \equiv 6.67430 \cdot 10^{-11} \cdot \frac{m^3}{kg \cdot s^2}$	Gravitational constant

Figure 4-4: The Global Definition operator.

#### 4.3.2. Comparison Equal To Operator

The **Comparison Equal To** operator is used in the following ways:

- Evaluating expressions used in conditionals and loops inside of programs. Conditionals include *If-Then-Else* constructs, and loops include *For* and *While* constructs. These are used inside of programs in Mathcad, which can be thought of as a complex version of a user-defined function. Programs are covered in Chapter 5.
- Establishing Constraints in Solve Blocks, which are used to solve systems of equations and perform optimizations. The latter is covered in Chapter 6.
- Documenting your calculations, as shown in Figure 4-5.

The **Comparison Equal To** operator can be entered from **Math > Operators** and is found in the Comparison group. The keyboard shortcut is the CTRL key and the equals sign.

Calculations:	
$W = \frac{4 \cdot g \cdot \Delta E}{r^2 \cdot (\omega_1^2 - \omega_2^2)}$	Formula for weight

Figure 4-5: Using the Comparison Equal To operator for documentation.

### 4.3.3. Symbolic Evaluation

As the name states, the **Symbolic Evaluation** operator allows you to evaluate expressions symbolically as opposed to numerically:

The image shows a grid with a light blue background and a grid pattern. At the top left, the text "Symbolic Evaluation" is written. Below it, the heading "Derivatives" is centered. There are six derivative formulas arranged in two columns and three rows. The first row contains  $\frac{d}{dx} \sin(x) \rightarrow \cos(x)$  and  $\frac{d}{dx} \tan(x) \rightarrow \tan(x)^2 + 1$ . The second row contains  $\frac{d}{dx} (a x^2 + b \cdot x + c) \rightarrow 2 \cdot a \cdot x + b$  and  $\frac{d}{dx} \arcsin(x) \rightarrow (-x^2 + 1)^{-\frac{1}{2}}$ . The third row contains  $\frac{d}{dx} \ln(x) \rightarrow \frac{1}{x}$  and  $\frac{d}{dx} e^x \rightarrow e^x$ . Below the derivatives, the heading "Indefinite Integrals" is centered. There are four integral formulas arranged in two columns and two rows. The first row contains  $\int \frac{1}{x} dx \rightarrow \ln(x)$  and  $\int \ln(x) dx \rightarrow x \cdot (\ln(x) - 1)$ . The second row contains  $\int e^{ax} dx \rightarrow x \cdot e^{ax}$  and  $\int (\sin(x))^2 dx \rightarrow -\frac{\sin(2 \cdot x)}{4} + \frac{x}{2}$ . Below the integrals, the heading "Definite Integrals" is centered. There are two definite integral formulas. The first is  $\int_a^b \pi \cdot x^2 dx \rightarrow \frac{(b^3 - a^3) \cdot \pi}{3}$ . The second is  $\int_a^b e^{-t} dt \rightarrow e^{-a} - e^{-b}$ .

Figure 4-6: Symbolic evaluation of derivatives and integrals.

The **Symbolic Evaluation** operator is available from **Math > Operators** and is found in the Evaluation and Definition group. It looks like an arrow pointing to the right and the keyboard shortcut is the CTRL key and a period.

The **Symbolic Evaluation** operator will not be used further in this book.

## 4.4. Variables

A variable is a placeholder for a number, mathematical evaluation, or other expression to be evaluated or used in other expressions.

All variables have a name defined by the user, and the names must conform to the following rules and conditions:

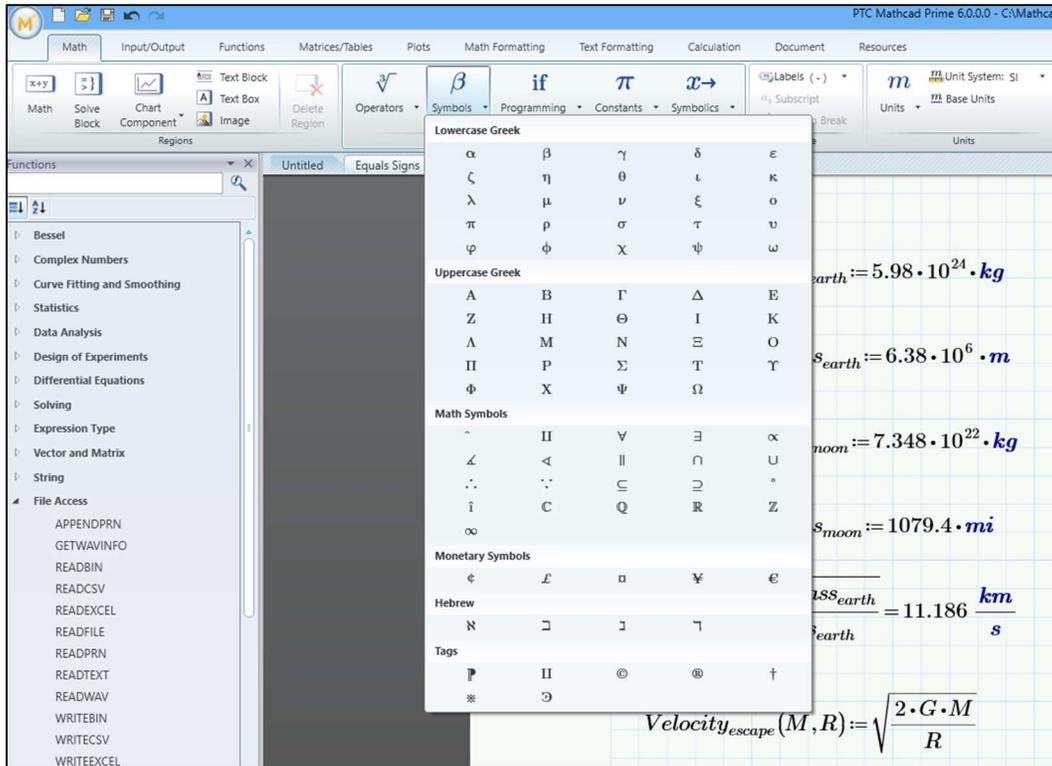
- Variable names can consist of upper- and lower- case letters from the English or Greek alphabets.
- Variable names can also contain the Hebrew letters Alef, Bet, Gimmel, and/or Dalet. These characters are available from the **Symbols** drop-down in the **Operators and Symbols** group on the **Math** tab. These characters do not have pre-defined shortcuts.
- The numbers 0 through 9, as long as a number is not the first character in the name of the variable.
- They are case-sensitive.
- There is no limit to the length of a variable name.

*Tip: When defining a variable for the first time, use a Text Box to explain the variable. Document as you go.*

The rules for naming a variable apply to functions as well. See section 4.5 for more information about [functions](#).

### 4.4.1. Greek Letters

Upper- and lower- case Greek letters can be accessed from the **Symbols** drop-down menu in the **Operators and Symbols** group on the **Math** tab:



You can also convert upper- and lower- case English alphabet letter to Greek by typing the keyboard shortcut of the Control key CTRL and the letter G on the keyboard. This will convert the immediately previously typed character into its Greek equivalent.

**Do not use Greek letters in the names of variables used as inputs or outputs for Creo Parametric integration! Creo Parametric does not support Greek letters.**

#### 4.4.2. Pre-Defined Constants

Mathcad has several pre-defined constants from math and physics. The math constants include:

- Infinity  $\infty$ , which is evaluated as 10 to the 307<sup>th</sup> power.
- The logarithm base e (approximately 2.71828).
- The so-called "circle constant" pi or  $\pi$ , which is the ratio of a circle's circumference to its diameter.

*Note: As a circle is defined as the set of points in two-dimensional space that are the same distance from a center point. This distance is the radius of the circle. Therefore, Tauists such as me consider the true circle constant to the ratio of a*

circle's diameter to its radius to be the true circle constant. This constant tau, or  $\tau$ , is approximately 6.28318 and equal to  $2\pi$ . Notice how often  $2\pi$  appears in equations and integrals.

The physics constants include, but are not limited to:

- The speed of light  $c$ .
- Planck's constant  $h$  and Planck's reduced constant  $\hbar$ , which is  $h$  divided by  $2\pi$ .
- The atomic mass unit  $m.u.$
- Avogadro's Number  $N.A.$

Note the use of  $2\pi$ , or  $\tau$ , in Planck's reduced constant.

These can be accessed from the **Constants** drop-down in the **Operators and Symbols** group on the **Math** tab:

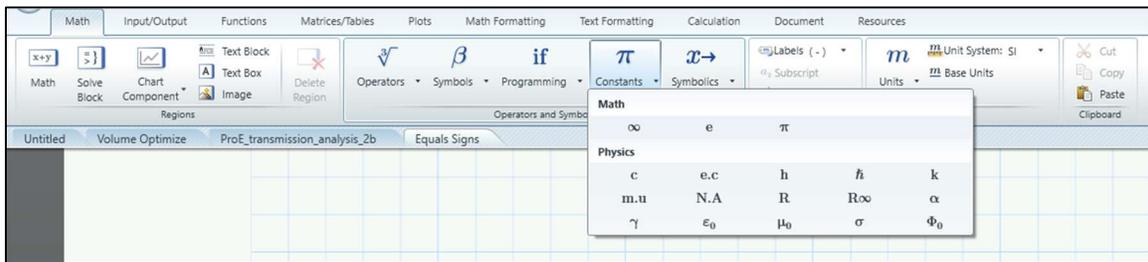


Figure 4-7: Mathcad Constants.

Many of these have a keyboard shortcut, which as always can be viewed from the tool tip when hovering your mouse over the icon.

When evaluated or used in expressions, these constants will appear by default in a dark green color:

$\infty = 1 \cdot 10^{307}$	$e = 2.718$	$\pi = 3.142$
$c = (2.998 \cdot 10^8) \frac{m}{s}$	$e_c = (1.602 \cdot 10^{-19}) C$	$h = (6.626 \cdot 10^{-34}) \frac{kg \cdot m^2}{s}$
$\hbar = (1.055 \cdot 10^{-34}) \frac{kg \cdot m^2}{s}$	$k = (1.381 \cdot 10^{-23}) \frac{kg \cdot m^2}{s^2 \cdot K}$	$m_u = (1.661 \cdot 10^{-27}) kg$
$N_A = (6.022 \cdot 10^{23}) \frac{1}{mol}$	$R = 8.314 \frac{kg \cdot m^2}{s^2 \cdot K \cdot mol}$	$R_\infty = (1.097 \cdot 10^7) \frac{1}{m}$
$\alpha = 0.007$	$\gamma = 0.577$	$\epsilon_0 = (8.854 \cdot 10^{-12}) \frac{s^4 \cdot A^2}{kg \cdot m^3}$
$\mu_0 = (1.257 \cdot 10^{-6}) \frac{kg \cdot m}{s^2 \cdot A^2}$	$\sigma = (5.67 \cdot 10^{-8}) \frac{kg}{s^3 \cdot K^4}$	$\Phi_0 = (2.068 \cdot 10^{-15}) Wb$

Figure 4-8: Evaluation of the pre-defined constants.

You can override these pre-defined constants with a definition operator:

$$c = (2.998 \cdot 10^8) \frac{m}{s}$$

$$c := 42$$

$$c = 42$$

Figure 4-9: Overriding a pre-defined constant.

#### 4.4.3. Subscripts vs. Vector and Matrix Indices

Variable names can include subscripts. For example, you may want to have variables  $v_i$  and  $v_f$  to denote initial and final velocity respectively. To create a subscript, when typing in a variable name, click the **Subscript** icon  in the **Style** group on the **Math** tab. Alternatively, you can use the keyboard shortcut of the CTRL key and the minus sign to define a subscript as you are typing the variable name in the graph paper interface.

A variable name can include more than one subscript if so desired.

However, vectors and matrices also use subscripts to indicate individual elements in the vector or matrix. To define an element in a vector or matrix, you can use the **Matrix Index** operator from the **Vector / Matrix Operators** drop-down command on the **Matrices / Tables** tab:

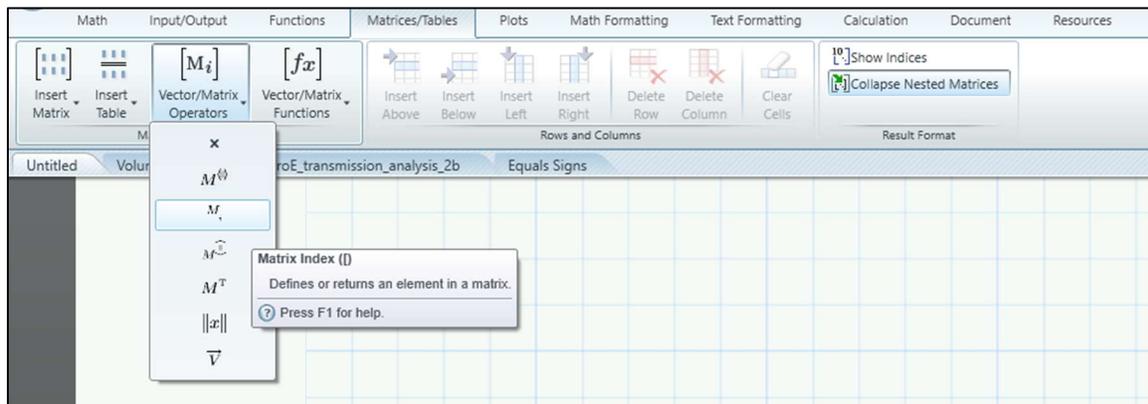


Figure 4-10: Matrix Index Operator.

The keyboard shortcut for the **Matrix Index** operator is the left bracket character [, located next to the letter P on standard keyboards.

Avoid confusion by using different letters and names for different variables with subscripts and matrix indices.

#### 4.4.4. Implied Multiplication

Mathcad also supports implied multiplication. For example,  $100x$  is evaluated as 100 multiplied by the variable  $x$ , and  $2\pi$  is evaluated as 2 times pi. There is no need to use the multiplication operator when typing in these expressions. (Numbers are not allowed as the first character in the name of a variable or function for this reason.)

#### 4.4.5. Imaginary Numbers

Mathcad supports the use of complex- and imaginary- numbers, which are denoted by the letters  $i$  and  $j$ . Both are evaluated to the square root of  $-1$ .

If  $i$  and  $j$  are used as variable names, implied multiplication is not supported. That is, if you want to evaluate 3 times the variable  $i$ , you will have to type the multiplication operator after typing in the number 3. Otherwise,  $3i$  is evaluated as 3 times the square root of  $-1$ .

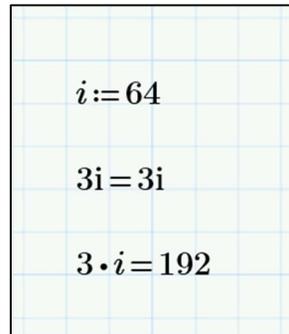

$$i := 64$$
$$3i = 3i$$
$$3 \cdot i = 192$$

Figure 4-11: Imaginary Numbers and Implied Multiplication.

## 4.5. Functions

A function is a defined operation that performs math on inputs and returns an output. The outputs can be real numbers, imaginary and complex numbers, strings, vectors, and matrices.

In PTC Mathcad there are two different kinds of functions that you can use:

- Over 400 different built-in functions from a variety of different areas of mathematics.
- User-defined functions that combine math and built-in functions.

### 4.5.1. Built-In Functions

PTC Mathcad Prime contains over 400 built-in functions that you can use in math regions, functions, programs, solve blocks, and any other mathematical expressions.

To use a function, you can type it in directly in the worksheet if you know its name and arguments. Otherwise, you can click on the **Functions** tab. Functions can be selected from popular groups including:

- Differential Equations
- File Access
- Solving
- Statistics
- Vector and Matrix



If you click on the **All Functions** icon, a panel will open on the left side of the screen listing all the functions grouped into 32 categories. Popular categories include:

- String editing.
- Interpolation and Prediction
- Log and Exponential
- Trigonometric functions such as sine, cosine, and tangent.

The Functions bar can be switched to list functions alphabetically instead of by category. It also contains a search field.

#### 4.5.2. User-Defined Functions

In PTC Mathcad, you can create your own custom user-defined functions. These functions have a name and the variables that are passed to them inside parentheses. For example:

$$f(x,y) := x + y$$

The same [rules for variable names](#), as described in section 4.4, apply to the name of functions. The inputs to a function can be numbers, strings, variables, vectors, and matrices.

The variables in the parentheses in the function definition do not need to exist prior to the definition. These variable names are used locally within the function definition.

As with defining variables, you will use the **Definition** operator to define the mathematical expression you want the function to perform on the right-hand side of the expression.